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Making Business Decisions under Uncertainty: a Comprehensive Framework[1]

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Abstract

This paper synthesises theoretical and methodological advancements in decision- making under uncertainty, with a focus on integrating the core components of the decision-making system. While prior literature has extensively explored individual facets of uncertainty management, this work centres on elucidating the decision- making process itself, particularly synthesising its constituent components and their operationalization into coherent decision rules. Building on foundational progress in probability theory and fuzzy set theory over the past century, we propose a comprehensive framework that unifies four interrelated dimensions: (i) conceptualizations of uncertainty, (ii) cognitive strategies for reasoning under uncertainty, (iii) model construction methodologies, and (iv) decision-making techniques. The analysis culminates in examining sustainability uncertainty, emphasizing its dialectical interplay with decision-making paradigms. Though the paper refrains from granular technical discussions of individual components, it prioritizes articulating the framework's theoretical coherence and practical utility. By bridging data-driven quantitative approaches with qualitative, context-sensitive strategies, this study advances a holistic perspective for navigating uncertainty, offering insights for researchers and practitioners in fields requiring adaptive decision- making systems.

Keywords: *Uncertainty, Risk, Probability, Fuzzy sets, Metaphor, Narrative, Decision Theory, Expected Utility Theory, Prospect Theory, Possibility Theory, Real Options.*

Introduction

Uncertainty has long captivated the minds of thinkers, researchers, entrepreneurs, and ordinary people throughout human civilisation. Commonly understood as the antithesis of certainty and complete determinism (predictability), uncertainty has been a subject of profound exploration and debate.

Since ancient Greek philosophy, attitudes toward uncertainty have been radical, rejecting determinism altogether. Socrates famously declared, "As for me, all I know is that I don't know anything," while Voltaire offered a more artistic perspective: "Uncertainty is an uncomfortable position. But certainty is absurd."

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In ancient times, people grappled with the uncertainty of the future and its inherent risks, lacking rational means to predict it. Instead, they turned to oracles, soothsayers, shamans, and other fortune-tellers to project what lay ahead.

Much later, humanity uncovered a fundamental law of physics that revealed uncertainty as a core property of the material world. This law, known as the "uncertainty principle," was first formulated by the renowned German physicist Werner Heisenberg. It asserts that it is impossible to simultaneously determine a microparticle's position and momentum with absolute accuracy. The boundaries imposed by this principle cannot be overcome, even with advanced measurement tools. Today, the uncertainty principle remains a cornerstone of quantum mechanics, which posits that every object in the universe exhibits both particle and wave behavior.

Beyond the material realm, it can be argued that uncertainty is an intrinsic property of all things, perhaps even a deliberate creation of some absolute force.

Recent events, particularly Russia's ongoing war against Ukraine, have underscored the threatening nature of uncertainty. This conflict has introduced the concept of *radical uncertainty* —a force capable of dismantling the established world order. It prompts us to question whether this order was ever perfect. Recognizing that perfection is

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unattainable, humanity is beginning to understand the necessity of a quantum leap toward a new state of existence. This leap would retain the inherent property of uncertainty while eradicating the factors that threaten humanity's survival— though new challenges may arise.

Russia's war against Ukraine has served as a stark reminder of the fragility of the global order, shattering its once-perceived solidity. However, there is a positive aspect to this upheaval. The war has heightened Ukraine's "degree of uncertainty" and that of its surroundings, revealing both the vulnerability of the current system and the opportunities it presents. For Ukraine and humanity, this crisis offers a chance to advance the next step in the evolution of humane history.

1. Decision-making as a system

We begin with the premise that meaningful human activity involves making reasoned decisions and implementing them. Nearly everything people do involves decision- making and its execution, so constructing decision-making theories is akin to describing human activity itself. When deciding, a person pursues a specific goal, often choosing from a set of available options. Decision-making is not about random selection but a purposeful activity. Thus, decision theory focuses on goal-directed behaviour in the presence of alternatives.

In everyday life, the decision-making process is often simplistic. The decision-maker, influenced by their psychological traits, selects an approach or criterion to identify the best alternative from their perspective. Sometimes, this decision proves correct and beneficial; other times, it is erroneous. The accuracy of a decision is ultimately tested by practice, which serves as the criterion of truth. A decision is deemed correct if it achieves the intended goal. However, decisions are always made under uncertainty, as the decision-maker rarely possesses complete information to guarantee success.

Fortunately, we are not required to make decisions every moment. Most activities involve alternating periods of decision-making and execution, and decision theory primarily concerns the former.

It is also important to consider who the "decision-maker" is and the conditions under which decisions are made. At the household level—such as deciding whether to buy a new refrigerator or repair an old one—decisions are often intuitive or based on simple financial considerations. However, more significant decisions demand more than intuition or basic calculations. These require systematic approaches, as the higher error cost can lead to severe consequences.

Modern decision-making approaches emerged in the mid-20th century through the collaboration of various academic disciplines. Decision theory is inherently interdisciplinary, applied equally by economists, statisticians, psychologists, political scientists, sociologists, philosophers, and entrepreneurs. For instance, a medical doctor's decisions are far from intuitive, as errors can cost lives. Similarly, a political scientist studies voting rules and collective decision-making, while a psychologist examines human behavior during decision-making, and a philosopher seeks to generalize and describe reality. Economists, in particular, have made significant contributions to decision-making techniques, given their focus on developing economic theories.

The overlap in decision-making approaches across different fields has enriched decision theory, as researchers with diverse expertise have applied their methods to similar problems.

Most decision-making techniques are quantitative, relying on mathematical models. However, not all decision-makers possess the analytical mindset required to develop such models. In such cases, non-quantitative models—often using narratives and metaphors—can be equally effective. We refer to these as *semantic models* . While the correctness of a decision is ultimately determined by practice, the internal conviction of the decision-maker and their team, based on semantic models, can be as strong as—or even stronger than—that derived from quantitative methods.

It is worth noting that most decisions are not instantaneous. They require time to reflect on the event or phenomenon at hand. The decision-making process is complex and demands a systematic approach, which we will explore in detail.

Let D represent a decision made to achieve a strategic goal. We consider it as a function of four conceptual variables:

$$D = f(U, P, M, T).$$

These conceptual variables have the following meanings:

$U \in (U_1, U_2, \ldots, U_K)$ represents "UNCERTAINTY", which refers to the type of uncertainty that a decision-maker takes into account when finding a solution to a problem;

$P \in \Re(P_1, P_2, \ldots, P_N)$ stands for "PARADIGM", which refers to the approach (the way of thinking) about uncertainty;

$M \in \mathcal{M}(M_1, M_2, \ldots, M_L)$ represents "MODEL", which is the tool that a decision-maker can use to describe a phenomenon or situation being considered;

$T \in (T_1, T_2, \ldots, T_S)$ introduces "THEORY", a set of methods for making a final decision based on the selected criteria.

The paper describes each conceptual variable and explores their interconnections. These components cannot be considered in isolation, as they are dialectically intertwined.

Uncertainty is the primary conceptual variable, forming the foundation of the system. It is an inherent state of nature and the world. To manage behavior effectively in the face of uncertainty, one must first understand how uncertainty operates.

Once we accept the inevitability of uncertainty, we must develop the right attitude toward it. Uncertainty is not solely negative; it also presents new opportunities, meanings, and values. By learning to think effectively about uncertainty, we can embrace it and harness its potential.

The probabilistic paradigm is the most common approach to

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assessing uncertainty, involving the evaluation of future events' likelihood. However, it is not the only method. Fuzzy sets, for instance, offer a more constructive way of thinking. Decision-makers must choose their preferred approach to envision the future and build a model.

In intelligent human activity, the model precedes decision-making. It formalizes the decision-maker's way of thinking into a specific image that prompts action. While mathematical models, expressed through symbols, are common, other methods— such as semantic models or graphical representations—are equally valid. Even works of art, like Beethoven's Ninth Symphony, can serve as models by inspiring action.

The final step in the system is making the decision. Once a model is established— whether probabilistic or otherwise— the decision-maker selects the best option based on specific criteria. With mathematical models, algorithms often determine the optimal choice, shifting some responsibility away from the decision-maker. However, non- quantitative methods place the entire burden of accountability on the decision-maker, increasing the risk of error.

In the following sections, we will delve deeper into each conceptual variable and its role in the decision-making process.

2. Uncertainty as a phenomenon

Uncertainty is an inherent property of our world and a consequence of our attempts to understand it. For decision-makers, grasping the intricacies of uncertainty is essential.

First, let's explore the sources of uncertainty. The generally accepted view identifies two primary types: *aleatoric uncertainty* and *epistemic uncertainty*. However, we propose introducing a third type, which we will call *semantic uncertainty*.

Aleatoric uncertainty arises from the stochastic nature of the physical world, which is inherently unstable and ever-changing. **Epistemic uncertainty**, on the other hand, stems from a lack of knowledge or understanding of events and phenomena. While aleatoric uncertainty is primary, epistemic uncertainty is secondary. For example, when guessing the outcome of a coin toss, we experience aleatoric uncertainty before the toss and epistemic uncertainty if the result is hidden. People often find epistemic uncertainty more unsettling, as it reflects a gap in knowledge.

Risk is closely tied to uncertainty. According to *Merriam-Webster's Collegiate Dictionary*, risk is defined as the "possibility of loss or injury," and taking a risk means "to expose to hazard or danger." This definition emphasizes the negative connotations of risk. However, Eastern philosophy offers a more nuanced perspective.

In Chinese, the character for risk combines two elements: "danger" and "opportunity" (see Fig. 2.1). This duality highlights that while risk involves the potential for loss, it also presents opportunities for gain if managed skillfully.

Fig. 2.1. Eastern Philosophy of Risk

The first hieroglyph is translated as "danger", and the second is "opportunity". In the best traditions of the East, the Chinese were able to very subtly note that, on the one hand, the risk is associated with the danger of losing something or even everything. On the other hand, it provides additional opportunities if you take advantage of the situation competently.

To illustrate this, consider a 2x2 matrix of possible errors in decision-making (see Fig. 2.2). Suppose you are faced with a critical decision, such as investing a large sum of money in a project. You can either accept or reject the opportunity, and your decision may be right or wrong. Two risks emerge: (1) rejecting a correct option (missing an opportunity) and (2) accepting a wrong option (making a mistake).

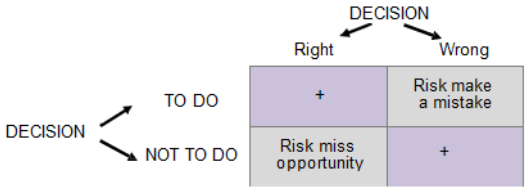

Fig. 2.2. The Error Matrix

People can be broadly categorised into two groups based on their approach to uncertainty: *ordinary* and *ambitious*. Ordinary individuals seek to eliminate uncertainty, striving for a more deterministic and predictable world. They avoid risks whenever possible. Ambitious individuals, however, embrace uncertainty. They view it as a source of opportunity, believing that greater uncertainty enhances the chances of discovering new meanings and creating value. As the saying goes, "Who does not take risks does not drink champagne."

Now, let us turn to the third type of uncertainty: **semantic uncertainty**. This arises from ambiguous interpretations of concepts, terms, or texts, which can lead to misunderstandings and erroneous decisions. To better understand this, we draw on **Nalimov (1989),** who posits that consciousness comprises a triad of meaning, texts, and language. Words and texts convey multiple meanings, modelled as probability distributions.

To ground our understanding of uncertainty, we explore the perspectives of Keynes and Knight. **John Maynard Keynes (1921)** regarded uncertainty as ontological, especially in social phenomena, and contended that probabilistic logic is better suited to our uncertain world than classical logic. **Frank Knight (1921)** differentiated between *risk* (where probabilities can be numerically defined) and *uncertainty* (where they cannot). While this distinction is theoretically intriguing, it holds limited practical relevance for decision-making.

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Bradley and Drechsler (2017) present a more nuanced taxonomy that categorises uncertainty into three types: ethical, option, and *state space uncertainty*. Ethical uncertainty arises when utilities cannot be precisely assigned to consequences, option uncertainty occurs when the consequences of actions are unknown, and state space uncertainty exists when the decision-maker cannot construct an exhaustive state space. While this framework is complex, it offers valuable insights into the nature of uncertainty.

For practical purposes, we suggest a simpler classification that centres on uncertainty as a state between *complete certainty* and *absolute uncertainty* (chaos). In a state of complete certainty, no alternatives exist, making decision-making trivial. In chaos, neither risks nor opportunities can be modelled or evaluated. Uncertainty exists between these extremes, enabling risk assessment and decision-making.

Chaos is a scientific concept distinct from randomness. Chaos theory explores systems susceptible to initial conditions, exhibit disproportionate cause-and-effect relationships, and are nonlinear. While chaos and uncertainty share the consequence of unpredictable outcomes, chaos lacks the patterns observed in uncertainty.

In both chaos and uncertainty, the decision-maker may or may not achieve their goal. The challenge lies in finding the right way of thinking, building an adequate model, and establishing criteria for decision-making. In the following sections, we will focus on decision-making under uncertainty, leaving chaos as an extreme case.

3. The Ways of Thinking

This system component reveals the inherent ambiguity in interpreting the concept of "thinking." From its earliest philosophical foundations, the process of thinking has been subject to diverse interpretations. Aristotle, for instance, grounded the process of thinking in the principle of worldview, positing that the perception of the natural world is unambiguous and finite. The notion of uncertainty later emerged in philosophical discourse. René Descartes, in his seminal work *Meditations on First Philosophy* (1641), introduced the famous dictum *Cogito, ergo sum* ("I think, therefore I am"), affirming the existence of the mind. However, Descartes could not establish a definitive correspondence between human thought and the natural world, nor did he provide a clear pathway to attain absolute truth. This limitation underscores the necessity of re-evaluating the nature of thinking itself.

Ludwig von Mises (1964) addressed the challenges of uncertainty and probability by developing praxeology, a universal deductive science of human action, and its subset, catallactics, which focuses on market behavior. Mises posited that uncertainty, stemming from the limitations of human knowledge, is a prerequisite for freedom of choice. He contended that most humans can achieve an understanding of reality through an approximation through probability.

George Edward Moore (1903) emphasized the importance of assessing the probability of all possible consequences of actions and determining their expected value. He viewed the traditional understanding of probability as a manifestation of rationality, albeit limited to the "near future." This perspective aligns with the broader philosophical recognition of the role of probability in rational decision-making.

Andrew Kolmogorov, the founder of axiomatic probability theory, highlighted the significance of probabilistic thinking as an intermediate between deductive logic and intuition. Probabilistic thinking revolves around the concept of "assumption," wherein individuals assess the likelihood of an event and make decisions based on this assessment. This approach is particularly evident in scenarios such as betting, where individuals must evaluate the probability of outcomes.
Probabilistic thinking can be categorized into three primary approaches: classical (logical), frequency, and subjective. The classical definition of probability emerged first, rooted in the desire to predict outcomes in symmetrical scenarios. The frequency approach, in contrast, relies on repeated experiments to estimate the probability of an event. The probability of event A is calculated as the ratio of the number of occurrences of A to the total number of trials. While this method provides objective estimates, its reliability increases with the number of experiments conducted.

Both classical and frequency interpretations of probability are objective, as they remain independent of the decision-maker's perspective. However, their applicability is constrained in practical scenarios where symmetry or adequate experimental data is absent.

Both classical and frequency interpretations of probability are objective, as they remain independent of the decision-maker's perspective. However, their applicability is constrained in practical scenarios where symmetry or adequate experimental data is absent.

Subjective probability incorporates the decision-maker's personal beliefs and psychological characteristics. It represents an individual's degree of belief in the occurrence of an event, particularly in the absence of empirical data or theoretical frameworks. The subjective theory of probability, developed by **Frank Ramsey (1931), Bruno de Finetti (1975), and Leonard Savage (1954)**, establishes a rigorous foundation for this approach. The Ramsey-De Finetti Theorem posits that a set of betting quotients is coherent if and only if it satisfies the probability axioms, as Kolmogorov formulated.

Savage (1954) further advanced the theory by linking subjective probabilities to decision-making, integrating the concept of expected utility. This practical application underscores the relevance of subjective probability in real-world scenarios.

Some authors have made extensions and critiques of subjective probability. **John Keynes (1921)** argued that subjective probability should adhere to the laws of logic, emphasizing rationality over personal caprice. In "*A Treatise on Probability"*, he contended that probability is a logical relation between evidential propositions and conclusions,

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independent of individual opinions. This perspective aligns with the Bayesian approach, which updates probabilities based on new information.

Amos Tversky and Daniel Kahneman (1982) identified cognitive biases in probabilistic judgment, such as representativeness, availability, and anchoring. These biases illustrate the heuristics individuals employ under uncertainty, often leading to systematic errors.

Karl Popper (1995) introduced the concept of propensity, suggesting that probability is an inherent property of experimental conditions. He argued that propensities generate observed frequencies and can be measured through frequentist probability.

Patrick Suppes (1984) integrated probabilistic concepts into metaphysical and epistemological frameworks, positing that natural laws are probabilistic rather than deterministic. This probabilistic ontology reconciles randomness with causal laws, providing a comprehensive foundation for rational thought.

Beyond probabilistic thinking, alternative frameworks such as Dempster-Shafer Theory and fuzzy logic offer distinct perspectives on uncertainty. **Dempster-Shafer's (1976)** theory provides probability interval estimates, accommodating incomplete information. Fuzzy logic, introduced by **Lotfi Zadeh (1996),** describes the compatibility of instances with semantic concepts, offering a nuanced representation of uncertainty.

Radical subjectivism, as proposed by **George Shackle (2010),** emphasizes the subjective and idiosyncratic nature of human judgment under uncertainty. Shackle's theory challenges the Bayesian approach, focusing on real-world decisions' mental processes and irreversibility.

In summary, exploring thought uncovers a spectrum of approaches to understanding uncertainty, ranging from classical probability to fuzzy logic. Each framework provides unique insights, emphasising the complexity and diversity of human cognition.

4. Modelling

Before making a decision and doing something, any reasonable person will definitely think. This is what the second component of the decision-making system tells us. But oftentimes, it is not enough to think about it. You should do this in a certain orderly way. That is where the concept of a model comes in. From the most general standpoint, a model is a formal structure, represented in semantic images, mathematical formulas, diagrams, and graphs, that helps us understand a process or phenomenon and make an effective decision.

First, let us agree that there is no perfect model. As ***George Box*** stated, "All models are wrong, but some are useful." If we wish to express the same idea in terms of the general system of decision-making outlined here, we could say that we are always encountering 'second-order' uncertainty: being unsure about our very model of uncertainty. In other words, by creating a model of uncertainty, we elevate the level of uncertainty for decision-making because we are uncertain about this model while striving to do our best.

Creating a model always occurs as a conversion of inputs to outcomes. The model transforms the initial information, in whatever form it may be, into a certain finite representation, so that with its help, a decision-maker can achieve the goal. The decision-maker must choose to determine the further course of events, and the corresponding action will follow this choice. Most often, this situation will soon happen again. It means you will need to make the next decision. Actually, this is the content of the life of a reasonable person, no matter who he is: a scientist, politician, commander, entrepreneur, etc.

A model is a typical form of knowledge formalisation. It encapsulates knowledge, explains it, and predicts it in various fields of human activity: economic models of market competition, sociological models of networks, geological models of earthquakes, ecological models, and psychological models of cognition.

In general, there are two ways of creating models. In the first option, we prepare for the decision based on quantitative criteria (Data-Driven Decision-Making). In the second version, the model does not use quantitative categories. In each option, we must trace the model's origin and connection to our way of thinking.

One might think that this image is exclusively a transformation of quantitative data. It's not. Texts and other non-quantitative representations can be used as input to the creation of the model, and meanings appear in the model's output. Creating a model is more of an art than a science. This art cannot be comprehended by observing it from the outside. The full involvement of decision-makers is needed.

Firstly, we consider data-driven modelling of uncertainty. Models based on quantitative criteria are quite well formalized. Going back to the paragraph «The ways of thinking», we must recognize that there are two ways of modelling quantitative data under uncertainty: probabilistic and fuzzy. One more approach can be used to model uncertainties in a set of alternatives, each of which has no preference over the others. We consider this method of modelling uncertainty as a case of probabilistic, taking the equal probabilities for each alternative.

It should be noted that ***probabilistic modelling*** historically appeared before fuzzy and received a more thorough development. As we mentioned above, there are three interpretations of probability: classical, frequency, and subjective. Subjective probability is most common when building decision-making models. There are simple models when the decision-maker assigns these probabilities and then calculates the criterion that will be the basis for decision-making by mutual analysis. In practice, the most common is the ***Bayesian approach***. According to this approach, a person first assigns prior probabilities and then combines them with observations using the Bayes rule. As a result, he arrives at posterior probabilities that serve as the basis for decision-

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making.

The following principles summarize the ideas of the Bayesian approach to modelling uncertainty. It's time to look at it in more detail. Three principles refer to the subject as a bearer of probabilistic beliefs:

1. The Bayesian approach follows probability axioms which are the same as those for classical and frequency probability.
2. The Bayesian decision-maker has a complete set of probabilistic beliefs. In other words, to each proposition, he/she assigns a subjective probability, *P(H)*. A Bayesian decision-maker can assign a degree of belief about everything. Therefore, Bayesian decision-making is always decision-making under certainty.
3. When exposed to new information, the event with conditional probability *P(A/H)* (the probability that A occurs, given that H is true), the Bayesian decision-maker changes his beliefs under new information according to Bayes' rule.

$$P(H/A) = \frac{P(H) \cdot P(A/H)}{P(A)}.$$

This rule works equally well for the personalistic (classical) meaning of subjective probability and for the rationalistic one assuming a unique admissible probability assignment (we discussed this difference, considering different views of subjective probabilities). The Bayesian approach postulates a subject-independent probability function. However, in both cases, the probabilities referred to are subjective in the sense that they depend on the information available to the subject rather than on the propensities or frequencies of the material world.

The fourth issue of the Bayesian approach closely deals with the decision-making process. It was suggested by ***Savage*** (1954). It states that the rational decision-maker chooses the option with the highest expected utility. It will be the topic of the next paragraph. Now we will focus only on the model that was proposed by Savage to create a clear system of decision-making in conditions of uncertainty.

To decompose this basic uncertainty, Savage suggests a convenient representation of a decision problem by a matrix of the kind exhibited in the table of Fig. 4.2.

	States of the world		
Options	S_1	...	S_n
A^1	C_1^1	...	C_n^1
⋮	⋮	⋱	⋮
A^m	C_1^m	...	C_n^m

Fig. 4.2. Decision Matrix

Savage's model of presenting decision problems shows that in trying to decide what to do, a decision-maker is uncertain about (i) what states and consequences there are,

(ii) what actions are available, (iii) which states of the world are actual and what the consequences are of acting. This model was the basis for choosing the best alternative. We will discuss this issue in the next paragraph.

Probabilistic modelling can be achieved using random events, variables, and stochastic processes. Now, we shall discuss approaches to constructing decision models that incorporate random variables, which may be discrete or continuous. Once again, we are referring to the Fig. 4.1 model. This time, random variables will serve as inputs.

Now suppose that the inputs of the model *X1, X2, ..., Xn* are random variables with a given probability density function (pdf) *f(xi)*. The outcomes of the model *Y1, Y2, ..., Ym* are random variables as well because each outcome depends on the inputs through the function:

$Y_k = (X_1, X_2, \dots X_n) \; \forall \; k = 1,2, \dots, m.$

The problem is to find out the pdf of each Yk given the pdf for each *k=1,2,...,m.*

In general, the 'inputs to outcomes' conversion models are very complicated, making it difficult to solve this problem analytically. This is where the Monte-Carlo simulation technique comes in. This technique is universal, meaning it has no limitations in terms of the content and complexity of the model. In essence, the Monte-Carlo method is an approach to modelling random variables with a given pdf utilizing the generation of pseudo-random variables by special software.

Let's consider a small illustrative example. Imagine a situation in which we want to assess the characteristics of the uncertainty of the Operating Profit of a portfolio of two products. The profit estimation model has the following inputs: Q – a volume of products sold; p – unit price; v – variable costs per unit; F - fixed costs. The model output is $Y = ((p_1 - v_1) + (p_2 - v_2)) \cdot Q - F$. All the inputs are uncertain and uniformly distributed in the interval [-10%,+10%]. We need to assess the uncertainty of Operating Profit. Fig 4.3 demonstrates the result of the modelling.

	#1	#2
Price ($)	80	120
Variable cost ($)	60	90
Volume (units)	500	300
Fixed Cost ($)	2300	
Target Profit ($)	12000	

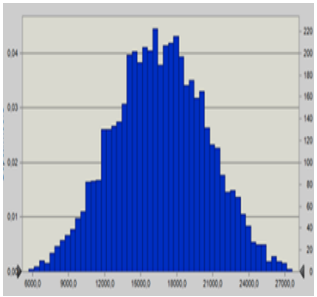

Fig 4.3. Monte Carlo simulation

We have simulated the uncertainty of operating profit, deriving its empirical probability density function, a model of this uncertainty. This provides a basis to evaluate the risks that operating profit will fall short of the value required by the manager.

Can the Bayesian approach be used in this design? Of course, yes, as it is also universal. Using the Bayesian approach, we can refine the prior probability distributions when we have the

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actual values of inputs.

Now, let's come to ***non-data-driven modelling***. Recently, a new notion appeared, "mental models"[2] (see **Hollins P., 2019)** as cognitive constructs that describe a person's understanding of the real world. A "mental model" is usually a semantic model: people understand the world by forming mental models. The general form of this hypothesis is not new: Even Immanuel Kant argued that there is no direct access to things-in-themselves. Therefore, it is necessary to build a mental model.

In the practice of building models, mainly three approaches are common **(see Page, 2021)**

- an approach of maximum embodiment, striving for maximum reliability,
- the method of analogies assumes that it is possible to abstract from concrete reality and use a suitable analogue,
- the method of an alternate reality does not intentionally represent or reflect reality.

Each approach deserves a detailed study, which will be done further. But now let's talk about what it means to make models effective, that is, convincing for decision-making. At the same time, it is necessary to consider that the decision will be made either by the person who created the model or by others to whom the model will be offered. It seems that ***narratives*** and ***metaphors*** are the most useful for constructing semantic ones. The narrative is the most suitable tool for the method of maximum embodiment and the method of analogies. Whereas the metaphor will create the most vivid images through analogies and alternative reality methods.

[2] Hollins P. (2019) Mental Models: 30 Thinking Tools that Separate the Average From the Exceptional. Improved Decision- Making, Logical Analysis, and Problem-Solving.

A narrative refers to any narrative text whose function is precisely to model a representation of a phenomenon in verbal form. This is a specific type of exposition that has a plot, and this distinguishes it from ordinary verbal descriptions or explanations. The "refined" texts make it possible to make the model bright and as accessible as possible for perception and subsequent decision-making. The plot presented in the narrative in a general sense is a certain degree of reflection on the understanding of reality. And finally, unlike predictive models based on data, the narrative model is built to convince and transform people's mental models by presenting a certain plot.

A metaphor is usually considered a bright artistic image. Remember Gogol's vivid metaphor from Dead Souls: "... *roads sprawled* in all directions, like crayfish caught when they were poured out of *a bag*." In creating a model, metaphor has a more important and, at the same time, more pragmatic purpose. Metaphor allows us to penetrate deeper into the essence of the object of modelling, going beyond our own object. Like a paradox, we better understand the essence of what is happening, going beyond it. This works equally effectively for both the analogy method (remember crayfish) and the alternate reality method.

Metaphor is the process by which one entity or state is described in terms originally intended to describe other things. Metaphor is the change of signs that are different in meaning but used in the same semantic contexts. For this reason, metaphor is most effective in building models using the method of alternative reality.

Unlike the traditional combination of concepts, metaphor has one undeniable advantage. Metaphor always combines a concept and a vivid manifestation of emotions. If, when building a model, it is possible to find an apt metaphor, this will allow not only to build an effective model but also to form an emotional field of attraction. The latter will be crucial in the decision-making process.

A ***Metaphor-into-Narrative*** – powerful tool for semantic models. Both narrative and metaphor provide mechanisms for making sense of the world and creating a model. While metaphors elaborate and articulate particular points in a narrative, the narrative provides meaningful connections between sometimes unrelated metaphors, suggesting a symbiotic relationship between the two.

Semantic models are just one non-data-driven method of modelling. Graphic models can serve as very useful for clear perception. A visual image in the form of a diagram, a canvas, or even a painting can help a decision-maker present the overall picture of the object of decision-making and draw the correct conclusion. If we turn to business applications, we can find as a vivid example the format of the model, which has the form of a canvas on which all the essential factors of building a successful business are structurally located. The Business Model Canvas *(see* **Osterwalder A., Pigneur Y. ,2010**). is a powerful strategic management tool used to document existing business models and develop new ones. It offers a visual chart with elements describing a firm's or product's value proposition, infrastructure, customers, and finances, assisting businesses in aligning their activities by illustrating potential trade-offs. All these points are getting together and can allow the decision-maker to develop a powerful strategy.

5. Making Decisions

So, being uncertain, having learned to think adequately and create models, we are ready to make decisions. There are two main approaches in decision theory: ***descriptive decision theory*** (sometimes called behavioural decision theory) and ***normative decision theory*** (sometimes called prescriptive decision theory). The first approach describes how specific people make decisions based on considerations beyond formal logic. Such descriptions may include behavioral patterns or sociological factors relevant to a particular decision. The second approach prescribes procedures for making decisions based on certain formalized logic and the application of quantitative criteria. It is assumed that a person behaves rationally and is not affected by behavioural patterns or sociological factors.

The descriptive theory is often associated with constructing a

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mental model, which uses metaphors and narratives in addition to the usual semantic images. And how vivid these metaphors and narratives will cause a person's emotions will depend on the degree of confidence of the person in the correctness of the decision made.

In normative decision theory, the decision is justified by using formalized criteria. The following two approaches are mainly used here. ***The first approach*** uses ***probabilistic models***. And this opens a broad palette of possibilities and practical applications in decision-making. We have already discussed probabilistic thinking and modelling, and now it's time to conclude this sequence with specific tools for decision-making based on probabilistic models. There is a special case of the first approach, which considers a situation with a set of alternatives with the same probability. It means that we eliminate probability issues while posing the making decision problem. The problem is choosing the optimal alternative from the set of possibilities for a given set of states of the world. All possible combinations of system states and options are considered, and the one that provides the maximum or minimum value of the assigned criterion is selected. In this point of view, it is possible to proceed without probabilistic modelling, and a simple set of possible options sets uncertainty. No probabilistic techniques are used for decision-making. We call this approach ***combinatorial***.

T***he second approach involves*** making decisions based on fuzzy sets and logic. This paper focuses on probabilistic techniques.

The ***Expected Utility Theory (EUT)*** deserves the most attention regarding applied aspects. Its founder should rightly be considered ***Danial Bernoulli*** in 1738. His main idea came from the famous St. Petersburg Paradox. ***Von Neumann and Morgenstern*** **(1947)** made a sweeping generalization of this theory. Their excellent task was to lay a rational foundation for decision-making under uncertainty according to expected utility rules. Thus, EUT received its first axiomatic characterization. In particular, they state a series of axioms about the individual's preferences over indifference classes of lotteries and offer proof that an individual obeying these axioms will follow the expected utility theory. In the normative interpretation, these axioms are regarded as tenets of rational choice and should be judged by their normative appeal. In fact, if an individual does not maximize his expected utility, he violates some precise axiomatic principles, which are rationally binding in his choice. Von Neumann and Morgenstern's expected utility theory has been generally accepted as a normative rational choice model. EUT states that the decisions of a decision-maker conform to an expected utility function of the outcomes. In practice, individuals should always choose the alternatives that offer them the highest utility under uncertainty, i.e., the alternatives that offer higher earnings (wealth) or the lowest losses ever.

Years after the contribution of von Neumann and Morgenstern, **Savage (1954),** proposed the first complete axiomatic ***Subjective Expected Utility Theory***, focusing on uncertainty. This theory is another relevant instance of the theory of choice under uncertainty, while the expected utility hypothesis was originally formulated to be used with objective probabilities. Savage introduced his new analytical framework. The primary assumption is the existence and joint uniqueness of utility and probability and the interpretation of individual choice under uncertainty as expected utility-maximizing behavior. In Savage's approach, probability is presented broadly, assuming the possibility of refining prior judgments with additional information. Savage subjective expected utility theory and the Bayesian rule for updating the decision-makers information still represent the orthodoxy in making decisions under uncertainty.

In analytical terms, Savage's approach is based on the expected utility of the set of options, i.e. weighted average value of utility for the decision-maker. In other words, if the decision-maker adheres to axioms of rationality, believing an uncertain event has possible outcomes *xi*, each with a utility of *u(xi)*, the choices of the individual can be explained by this utility function combined with the subjective belief that there is a probability of each outcome, *P(xi)*. Therefore, the subjective expected utility is the resulting expected value of the utility:

$$E(U) = \sum_{i=1}^{N} u(x_i) \cdot P(x_i).$$

As we can see, the technique of using EUT is quite simple. Here is an example. Suppose there are two options, P1 and P2:

P1	Wealth	Prob.
Low	50,000	0.4
High	500,000	0.6

P2	Wealth	Prob.
Low	100,000	0.5
High	500,000	0.5

We should decide which is preferable from the point of view of EUT. We calculate the values of the utility function for each outcome as *u = Ln(Wealth)* and then compute the expectations: *E[u(P1)] = 0.40·u(50,000) + 0.60·u(500,000) = 0.40·1.6094 + 0.60·3.9120 = 2.991 E[u(P2)] = 0.50·u(100,000) + 0.50·u(500,000) = 0.50·2.3026 + 0.50·3.9210 = 3.107*

Under assigned probabilities, the decision maker must choose option *P2*.

EUT allows determining the relations of decision-makers to risk. Regarding risk, there are three groups of decision-makers: risk-averse, risk-neutral, and risk-seekers. Risk-averse decision-makers have a convex utility function. Risk-neutral people have a linear utility function. They would be indifferent between choosing a gamble on an uncertain outcome and a prospect with certainty. Risk-seekers have a concave utility function. They would rather gamble on the uncertain outcome than take the expected value of a prospect with certainty.

Tversky and Kahneman (1982) suggested the ***Prospect Theory***, which describes risk choice theoretically. The Prospect Theory differs in many ways from EUT, where

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decision-makers determine the value of total wealth. In contrast to some generalizations of the theory of expected utility, Kahneman and Tversky derived their theory of prospects from empirically identified and documented features of the behavior of actual respondents under uncertainty. Based on experimental studies, prospect theory makes a paradoxical conclusion: people are likelier to take on more risk to avoid losses than to receive an additional premium at high risk. Losses have a more significant effect than gains of equal size, known as loss aversion. According to this theory, the investor is free to hold stocks that depreciate but sell those that are rising in value. So, in the joke "a strategic investor is an unsuccessful speculator", there is some truth. "I know prices will still jump in the future; then I will sell my shares." Such reasoning is familiar to many.

Prospect theory revealed another feature of decision-making: people inadequately perceive probabilities. Psychologically, the individual overestimates small probabilities and underestimates medium and large ones. What's more, people choose to ignore a priori probabilities in exchange for minor data and analogies. Based on the nonlinear nature of the probabilistic value function used in prospect theory, the authors explain that people's emotional perception of events creates their probabilistic interpretation.

In practice, the term "decision-making" refers to the selection of a particular option and its subsequent implementation. However, there are often instances when the decision- maker, having reached a conclusion, still considers whether its implementation should commence immediately. A typical example of this is investment decisions, which entail a lengthy implementation period, thus increasing uncertainty and, consequently, the risks associated with the loss of invested funds. Within the probabilistic approach to decision-making, the method of **real options** is recommended. This method assesses potential approaches to implementing the decision in a manner akin to evaluating the purchase or sale of option contracts in the stock market. The primary distinction between real and financial options is that a real option is not a security. It does not circulate within the derivatives market, where it could be sold or purchased. The underlying asset of a real option comprises future management decisions that can be made concerning a specific development project.

A real option is a right, but not an obligation, to make and implement a decision in the future. The uncertainty of current conditions dictates this possibility. It is important to emphasize that the technique of real options allows you to quantify decision-makers' potential to adapt to changes. Adaptation is the most important property of systems that will enable you to reduce losses caused by uncertainty. Having the capacity to adapt can significantly reduce the negative impact of uncertainty.

The most significant property of a real option is that it should be exercised only when profitable. In economic activity, real options are peculiar in that they allow you to increase the value of development projects and, as a result, the value of the company. The application of real options is especially relevant in countries with high uncertainty.

Let’s now come to the special case of the probabilistic approach, which we call combinatorial. The decision-making technique is simplest and most transparent when uncertainty is represented as a set of alternatives unrelated to probabilistic. The decision is made by a simple combinatorial search of alternatives, from which one is chosen since it meets the criterion assigned in advance. Thus, the decision made directly depends on the criterion adopted. And there are several such criteria. The basic idea of any criterion is to replace a whole set of values with a single numerical indicator that characterizes this set from a certain point of view. Here is a list of such criteria: Wald's criterion; the "maximax" criterion; Laplace's criterion; Savage's regret criterion; Hurwitz's criterion.

Wald's criterion is the most "cautious”: the optimal alternative would be the one that provides the best outcome among all possible alternatives under the worst set of circumstances.

The "maximax" criterion is the opposite of Wald's criterion. If Wald’s reflected the view of the ultimate pessimist, then Maximax corresponds to an attitude of extreme optimism. All attention is paid only to the best outcomes.

Laplace's criterion is based on the principle of insufficient justification. Since, within the framework of the information approach in a situation of uncertainty, the probabilities of states are unknown, there is no reason to assert that they are different. Therefore, it can be assumed that they are the same. According to Laplace's criterion, the average value of outcomes is used as an estimate of the alternative.

Savage Minimax Regret Criterion is based on the following justification. Alternatives are evaluated based on the so-called "regret matrix". For an arbitrary alternative and a particular state of nature, the value of "regret" is equal to the difference between what the alternative provides and how much the maximum can be gained in a given state. From an economic point of view, the amount of "regret" can be interpreted as a lost gain compared to the maximum possible in each state of nature. The Savage criterion reflects the largest possible shortfall in winnings for a given alternative, the reason is that the less you can lose, the better.

The classical **Hurwitz’s criterion** considers only the extreme outcomes of each alternative. It can be viewed as a weighted average of the best and the worst uncertainty realizations. It allows considering the decision-maker's subjective attitude by giving these outcomes different "weights". The "optimism coefficient" λ, $0 \leq \lambda \leq 1$ is introduced into the criterion calculation, so if it is close to 1, the decision-maker feels optimistic and pessimistic otherwise, if λ is near zero.

We cannot conclude which criterion is more correct. The decision-maker chooses the criterion by himself. This can be considered a kind of manifestation of democracy in the decision-making theory.

It should be noted that the probabilistic approach, including

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the combinatorial case, is presented in decision theory much more thoroughly than the fuzzy approach, as evidenced by the number of techniques and approaches discussed above.

At the end of this section, we devote some attention to ***Game Theory*** as an important stage in the development of decision-making in conditions of uncertainty. The main type of uncertainty considered in game theory is uncertainty regarding the behavior of game participants under conditions of conflicts of interest.

Presently**,** Game Theory is a mathematical discipline that studies the resolution of conflicts between players and the optimality of their strategies. Conflict can refer to different areas of human interest: most often, it is economics, sociology, political science, cybernetics and military affairs. Conflict is any situation in which the interest of two or more participants, traditionally called players, is affected. For each player, there is a certain set of strategies that he can apply. Intersecting, the strategies of several players create a certain situation in which each player receives a certain result, called a win, positive or negative. When making decisions, it is necessary to consider not only obtaining the maximum utility for the player but also the possible steps of the enemy and their impact on the situation as a whole.

Game theory originates from the same work by ***von Neumann and Morgenstern*** (1947), which discusses the expected utility theory. In different terms, von Neumann and Morgenstern analyzed the strategic behavior of players in noncooperative zero- sum games in which no pure strategy equilibrium exists. In such games, the equilibrium may require the employment of mixed strategy. By adopting the axiomatic approach to depict the decision maker's preference in relation to the set of objective risks, von Neumann and Morgenstern identified necessary and sufficient conditions for the existence of a utility function on a set of outcomes that captures the decision maker's risk attitudes and represented his/her choice as expected utility maximizing behavior.

John Nash (1951) developed methods of analysis in which all participants either win or fail. These situations are called "Nash equilibrium". According to his theory, the parties should use the optimal strategy, which creates a stable equilibrium. It is beneficial for players to maintain this balance, as any change will worsen their situation. These works of Nash made a serious contribution to the development of game theory, and mathematical tools of economic modelling were revised. In particular, John Nash showed that the classic approach to the competition of Adam Smith, when everyone is for himself, is not optimal.

It should be emphasized that game theory is a very complex field of knowledge. When referring to it, a decision-maker must be careful and clearly know the boundaries of the application. Too simple interpretations are fraught with hidden danger.

6. Making Decisions under Sustainability Uncertainty

When it comes to the future of mankind, the uncertainty surrounding sustainable development is a crucial factor to consider. The fate of the planet and all life on it hangs in the balance, making it a top priority. One reason for paying crucial attention to this uncertainty is that sustainable development strategies have long-term time horizons, while entrepreneurs tend to plan for shorter periods. Despite this, these entrepreneurs are still keen to engage in active PR efforts. They understand that positive publicity can drive sales growth. This paragraph outlines the unique challenges involved in making decisions related to sustainable development and suggests a conceptual framework to guide these decisions.

Sustainable development has become an increasingly discussed and important topic in the face of global environmental issues such as climate change, resource depletion, and pollution. Despite being a necessity for a more stable and equitable future, many businesses have been slow to acknowledge or prioritize sustainable development. However, as public awareness and pressure grow, long-term economic benefits become more evident, and regulatory policy evolves, it is likely that sustainable development will be inevitable, even for the most resistant businesses. Understanding the importance of sustainable development in global discourse has made the public much more concerned with companies' environmental footprints. Social media activism, boycotts, and consumer advocacy have made businesses increasingly aware of the need to examine their practices. Companies are incentivised to adapt to more sustainable practices as the public demands add value to environmentally friendly products and services.

Further, we will define and describe a conceptual framework for the decision-making process related to business sustainability activities. This means essentially paying closer attention to current operating activities through continuous budgeting, such as attracting funds for sustainability issues like reducing environmental pollution, minimizing the use of non-ecological raw materials, and covering costs associated with sustainable communication, among others. In addition to this, the framework also covers capital budgeting decisions realized through investment projects that focus on environmental protection and corporate social responsibility activities. The point is that Sustainable Development offers significant long-term financial advantages for businesses willing to recognize and capitalize on them. Investments in resource efficiency, renewable energy, and waste reduction can lead to significant cost savings and competitive advantages over time. Adopting circular economy practices can ensure businesses extract maximum utility and minimize waste in their supply chains. Innovative and sustainable technologies also present ample opportunity for growth and differentiation in the market.

Governments are stepping up to address the environmental crisis by implementing stricter regulations that encourage sustainable business practices. They are introducing policy instruments such as carbon pricing, renewable energy subsidies, and environmental impact assessments to guide companies towards sustainable development. Businesses that

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fail to comply will face negative consequences that include penalties and reputational damage, making it necessary for them to adapt to these regulatory pressures.

Given the imperfections of the real world of business, it is possible that some businesses may not achieve sustainable development. However, it is inevitable for most as the world collectively moves towards a more environmentally-friendly future. As public awareness of sustainability grows and as long-term economic benefits and regulatory environments evolve, businesses will ultimately be compelled to adopt sustainable practices. Companies must acknowledge the importance of sustainability, allocate the necessary resources, and adapt accordingly in order to thrive in an increasingly environmentally conscious global market.

The principal variable to consider in a sustainability framework is time, particularly the short-term and long-term consequences of actions. Businesses must evaluate both immediate concerns and their long-term impact on society and the planet. Understanding that sustainable development is a dynamic process with varying time horizons is crucial for balancing immediate priorities with future goals. Sooner or later, all of humanity, including businesses, will understand that sustainable development will become a necessary and inevitable feature of human existence.

Let D represents a decision made to accomplish a sustainable development goal. We will consider it as a function of the four conceptual variables altogether, as outlined below

$D = f(t; U, R, P)$,
where $t \in (0, \infty)$ is time,

$U \in (U_1, U_2, \ldots, U_K)$ represents "UNCERTAINTY", which refers to the type of uncertainty that a decision-maker takes into account;

$R \in \Re(R_1, R_2, \ldots, R_N)$ stands for "RISK", which refers to the approach (the way of thinking) about uncertainty;

$P \in (-\infty, \infty)$ represents "PROFIT", which can be considered a main result of business activity.

Uncertainty is inherent in decision-making processes, particularly when addressing environmental and social issues. This uncertainty arises from fluctuations in global markets, unforeseen technological advancements, climatic changes, and shifting political landscapes. A conceptual framework for sustainability should account for these uncertainties and provide the means for being resilient and adaptable, thus enhancing the capacity to adjust to unforeseen changes.

Here is a list of the main factors contributing to sustainable uncertainty, which can be classified as either aleatory or epistemic uncertainty: *climate change, rapid technological advancements, economic instability, political instability, population growth and urbanisation, globalisation, resource scarcity, social and cultural factors, and policy and regulatory changes, unforeseen events.*

Despite these well-defined sources of uncertainty, specialists engaged in sustainable development do not clearly and unambiguously understand each one. This creates an additional source of uncertainty, specifically in the interpretation of each source. For example, it is difficult to define globalisation as a source of uncertainty in a universally accepted way. This creates secondary uncertainty, which is likely due to semantic uncertainty.

It is crucial to stress that almost all studies on sustainability assessments compare different alternative scenarios to determine which alternative may contribute to more sustainable development. Although there may be global boundaries, it is challenging to assess the extent to which a particular product, policy, or institution can contribute to fulfilling them.

Risks encompass the potential probability and severity of undesirable outcomes resulting from today's decisions, especially the risks arising from not recognising the importance of sustainable issues. A sustainability framework should entail evaluating and managing economic, social, and environmental risks. Effective risk management can limit negative impacts on resources, climate, and human well-being, ensuring the long-term success and sustainability of projects and initiatives.

There are two groups of risks associated with sustainability uncertainty. The first group includes risks at the macro level. Without exception, all enterprises in the country are exposed to these risks. The second group of risks consists of those that the business creates for itself (in addition to the risks of the first group) without paying tribute to the importance of sustainable development issues.

In the first group, we can confidently include the following risks: environmental degradation, the acceleration of climate change, economic consequences, public health concerns, and social inequality.

Sustainability uncertainty presents a significant risk to businesses due to the growing focus on sustainable practices, heightened public awareness, and the evolving legal and regulatory frameworks. These factors have made businesses more susceptible to sustainability-related risks. As consumer interest in sustainability increases, businesses that overlook environmental concerns risk harming their ***public image, which can adversely affect their reputation and brand value***. Failing to address environmental, social, and governance (ESG) issues may undermine customer trust and loyalty, particularly as consumers place greater importance on sustainability in their purchasing decisions. To protect their reputation and ensure long-term success, businesses must prioritise sustainability initiatives and actively strive to reduce their environmental and social impacts.

Neglecting sustainability issues can also result in significant ***operational inefficiencies***. The costs related to addressing environmental damage or retrofitting facilities to meet evolving regulatory standards can be considerable. Moreover, consumer preferences are shifting towards ethically sourced and environmentally friendly products, and businesses that do not prioritise sustainability risk lagging behind competitors in

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terms of innovation. To stay competitive, companies must anticipate future market demands and incorporate sustainability into their strategic planning. A lack of emphasis on sustainable innovations may render businesses obsolete as consumers and industries increasingly seek eco-friendly solutions, products, and services.

The potential for stricter ***environmental regulations*** poses another significant risk to businesses unprepared to adapt to new legislation. The regulatory landscape's ambiguity can further complicate decision-making processes and delay investments. Companies must proactively monitor regulatory developments and implement measures to ensure compliance, thereby mitigating the risks associated with regulatory uncertainty.

Moreover, ***investors and financial institutions*** are becoming increasingly aware of the risks linked to unsustainable business practices. Consequently, they are more inclined to support companies that prioritise sustainability, as these organisations exhibit lower long-term risks and greater growth potential. A notable example is BlackRock, one of the world's largest asset managers, which has significantly intensified its focus on sustainable investing. A significant portion of its assets under management is now allocated to environmentally friendly and socially responsible investments, mirroring the broader trend in the financial sector.

It is worth concluding the above discussion with a simple and obvious conclusion. If a country fails to recognize the risks associated with sustainable practices, it will have no future. Even if a country is committed to sustainability, a business will not survive if it cannot adhere to responsible and sustainable practices.

A sustainable conceptual framework should recognise that businesses need financial sustainability to survive and expand. Additionally, the framework maintains that the primary business objective is ***Profit***, which allows for investment in sustainable practices and technological advancements, promoting economic and environmental sustainability. Balancing economic objectives with principles of environmental protection and social equity is essential to ensuring long-term resilience and shared prosperity.

The conceptual variable of **Profit** plays a dual role in companies' commitment to sustainability. A decision regarding investments in sustainable development can be represented by a convex function. On the one hand, if a company does not pay adequate attention to the risks associated with sustainability, it may experience a decline in profits. This situation prompts the company to investigate the causes of this adverse phenomenon. In many cases, numerous losses in efficiency are found due to insufficient focus on sustainability issues. As a result, the company must make decisions to rectify the situation, which often involves enhancing strategy and attracting investment to support sustainable development. On the other hand, if a company experiences increased profits, it will have more resources to invest in sustainable development. If the company's management and owners firmly advocate for sustainable development, they will invest in enhancing sustainability, believing that this will lead to higher profits.

Based on the results of the aforementioned discussions, it is important to acknowledge the impact of the first variable in the conceptual model—**time**. Time is constantly evolving, and as it progresses, humanity and businesses are becoming increasingly aware of the necessity for sustainable development. This awareness stems from both universal values and the pragmatic influences of factors essential for business survival in the current environment. It is crucial to recognise that the transition to sustainable development cannot be deferred to the future, as procrastination in this regard is detrimental. Consequently, it is necessary to (1) identify the factors of uncertainty that are directly related to the sustainable development of the company's business, (2) assess the likelihood and severity of the repercussions of insufficient attention to sustainable development issues, and (3) analyse the dynamics of business profits and establish the extent of dependence of profits on sustainable development factors through factor analysis. While such studies cannot be conducted hastily, they are undeniably worthwhile. Should businesses postpone their transition to sustainable development, they risk losing their competitive edge and finding themselves at the bottom of the industry's major players. The phenomenon of an underdog triumphing in horse racing cannot apply here. It is impossible to outpace the frontrunners, who have heavily invested at the appropriate time in sustainable development, thereby granting them a robust and competitive advantage.

7. Conclusions

This paper has presented a comprehensive framework for understanding and navigating business decisions under uncertainty. By synthesizing advancements in decision-making theory and methodology, we have articulated the interconnectedness of four key dimensions: conceptualizations of uncertainty, cognitive strategies for reasoning under uncertainty, model construction methodologies, and decision-making techniques. This framework emphasizes the importance of not only understanding the nature of uncertainty (aleatoric, epistemic, and semantic) but also adopting appropriate paradigms for thinking about it, from probabilistic reasoning to fuzzy logic and narrative approaches.

We have highlighted the crucial role of model construction, emphasizing that models, while imperfect, serve as vital tools for formalizing thought and guiding action. Both data-driven (probabilistic, Bayesian, Monte Carlo) and non-data-driven (semantic, narrative, metaphorical, graphical) models offer valuable perspectives for understanding complex phenomena. The choice of model depends on the specific context and the decision-maker's cognitive style. Ultimately, the goal is to create a model that effectively captures the relevant uncertainties and facilitates informed decision-making.

Furthermore, we explored a range of decision-making techniques, including Expected Utility Theory, Prospect Theory, Real Options analysis, and combinatorial approaches.

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Each method offers a different lens to evaluate alternatives and manage risk. The choice of technique depends on the specific characteristics of the decision problem and the decision-maker's risk preferences.

Finally, we examined the specific challenges of decision-making under sustainability uncertainty. This domain presents unique complexities due to the long-term time horizons and the intricate interplay of economic, environmental, and social factors. We proposed a framework for navigating sustainability decisions that consider uncertainty, risk, and profit over time. Crucially, we argued that embracing sustainable practices is not just ethically responsible but also essential for long-term business viability. Ignoring sustainability risks can lead to reputational damage, operational inefficiencies, regulatory penalties, and, ultimately, business failure.

In summary, this framework offers a holistic perspective for navigating uncertainty in a rapidly changing world. By integrating quantitative and qualitative approaches, it provides valuable insights for researchers and practitioners across various fields. Further research could explore the granular details of specific components within the framework and examine their application in diverse decision-making contexts. The ultimate objective is to develop adaptive decision-making systems that enable individuals and organizations to thrive in the face of uncertainty and contribute to a sustainable future.

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